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Comprehensive Approach to Improve Identification Capabilities

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Summary

The process and the prototype presented here, are dedicated to improve the overall identification capability. This is aimed to be achieved by making available all identification related information, - i.e. local and remote data -, fusing and interpreting them, and supporting the decision process by offering a recommendation together with all explanation that might be desired.

The paper presents a solution that uses the Identification Data Combining Process (IDCP) according to draft STANAG 4162 as baseline. The prototype, assisting in identifying airborne objects, is the result of an experimental system using simulated as well as live data in a German Control and Reporting Centre (CRC).

1. Introduction

Motivation The military identification function asks for the identity or at least for a classification of an object under consideration. The performance has essential impact on the success of military missions and a reliable and rapid identification can be seen as force multiplier. Identification is a tri service function which is performed by various host systems under various conditions. I.e., in different alert states from peace to war, under various scenario conditions - e.g. a mixture of civil and military activities -, and different not in advance known compositions of own or enemy forces in e.g. joint, combined operations. To maintain always a complete picture of activities, continuous identification covering all objects of interest and being available in time is required.

There are various sensors and sources, including procedures, delivering information from which the identity or the category of an object can be inferred. As long as coverage, reliability and timeliness are not guaranteed by one source alone, all information obtainable and related to an object needs to be combined in order to make the best assessment of all information available. Such a combination would improve the coverage and substantially reduce uncertainty by exploiting the synergy of various sensors and sources. Implemented as an automated, real time process it would rapidly deliver results and improve the situational awareness.

Challenge A concept to improve the identification capability as indicated above would require interoperability that allows to exchange and unambiguously interpret outputs from sensors and sources. Such a fusion system should be available for all host systems with (potential) identification tasks. It should cover the common kernel of identification functions, i.e. the fusion and interpretation of received information, and should be adaptable to any specific host system's needs like the lay-out of the identification function or the interaction with the operator. The fusion system needs to be flexible versus the various environmental conditions (scenarios, groups of objects to be distinguished) in order to make the best assessment of the obtainable information. In summary, such an approach would comprehensively improve identification capabilities by providing and assessing all obtainable information.

Approach The fusion concept presented here, complies with the requirements by employing Bayesian principles together with a flexible choice of what distinction is relevant for identification and how risks have to be assessed. It provides standard formats for the outputs of all sensors and sources, a fusion component, the interpretation of discriminated target attributes with respect to identification, and the derivation of a recommendation within the range of decision alternatives of the hosting system. It can be used within any scenario in being provided with data describing the perception of composition of forces.

2. The Concept

Subsequently the principles of the approach are mentioned.

The concrete employment of sources needs a careful analysis and sometimes specific adaptations in order to keep the process simple while making the best use of the principles.

Each source output needs to be associated to the object of consideration in the sense that the output refers to the object.

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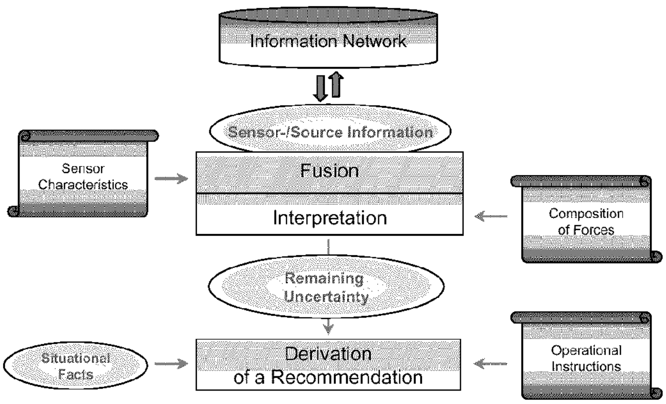
Conversion In order to express source outputs in a standardised format for further treatment, each source type is characterised by the set of target attributes it is able to discriminate. This set of attributes is used to convert each possible source output according to the Bayesian approach into an likelihood vector, a set of conditional probabilities referring to the attributes. In this way each source output is equivalently expressed by an likelihood vector describing what is discriminated and how good it is discriminated. Data or algorithms determining the likelihood vector values are contributing as a priori data to the process expressing the sources performance. These source dependend likelihood vectors reflect now the sources contribution to the process and are not yet interpreted with regard to allegiances or other specific operational, environmental aspects that are important for identification. Data exchange takes place at this level of not yet interpreted information in order to keep control on the data sources and not to loose pieces of information. As each source output corresponds to a predefined likelihood vector, the amount of data to be exchanged can be significantly reduced.



Data Flow and Processing

Fusion, Interpretation Fusion takes place at the level of source declarations – expressed in likelihood vectors - which might be locally or remotely obtained. The conditional independence of measurements and observations, i.e. source declarations, allows to combine them by multiplication of the corresponding likelihood vectors. To interpret the fusion result with regard to the attributes needed for identification (like allegiance) a new set of a priori data, used only once in the process, is needed. In principle this is an a priori distribution of the combination of all distinguished target attributes together with those needed for identification. Under some often justifiable assumptions (conditional independence of distinguished target attributes) the granularity of such a distribution can be significantly reduced.

The result so far is a posterior distribution over target attributes required for identification like own, enemy, and non aligned forces or these in combination with civil and military allegiance. As the process is mathematically consistent, the posteriors exactly express the achievable reliability in terms of allegiance.

Risk Assessment The posteriors are an important basis for the identification decision, however, in addition the decision depends on some situational facts (like alert state, the targets position - in case of airborne objects - in the airspace, or collateral data), operational procedures and operators judgement. To support the operator, a risk assessment is performed that delivers a recommendation out of the set of possible decision alternatives. Situational facts, like alert state determine this set of alternatives. For each combination of situational facts a loss table needs to be prepared that contains for each combination of allegiance and decision alternative a loss value reflecting the loss (military risk) taking place if the allegiance would be true and the alternative selected. In this way operational assessments and procedures are reflected in the process. Subject to the situational facts, for each alternative the respective loss values are 'weighted' by the posterior likelihood vector to determine the risk for each alternative. After assessing the complexity of the decision situation, the alternative with the minimum risk value assigned will be recommended.

Peculiarities

The approach defines a specific data fusion system, which is specifically designed for identification purposes. It covers the common kernel of the identification function and can be easily laid out for the different purposes of identification. It is open for any source type including future ones. As fusion takes place at a level where only source information is combined, an optimal exploitation of information from local and remote sources is reached.

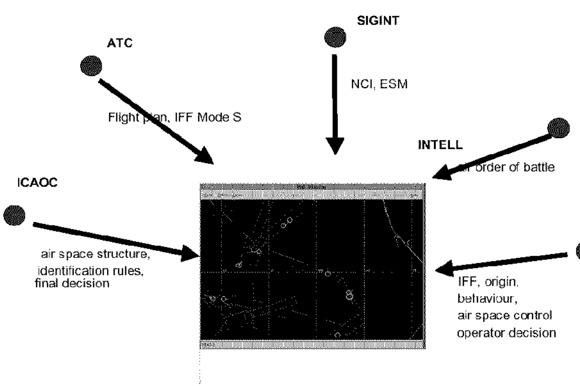
As it is mainly controlled by clear defined data (a prioris, loss values), it can easily be adjusted to any operational condition.

3. Adaptation

As indicated above, the adjustment to operational procedures and specific identification tasks can be easily achieved by the selection of appropriate structural elements and data.

Adaptation to Host Systems The system can be designed as a collection of modules with clearly defined interfaces. An implementation into a host system would mean to adapt it to the host system specific needs by adding some software parts. This would comprise adaptations to the HMI and the possibilities to interact with the system, as well as interfaces to various databases and to the various sources of

Example of Contributing Information



information. The latter could e.g. comprise the connection to a track source, and to locally as well as remotely available sources of identification information.

Adaptation to Architectures Any operational architecture can be supported by the system. It is possible to use the system as single node solution, treating only locally available data, it is however prepared to work in a netted environment in order make use of possible synergy. Different nodes in such a network could obtain the whole system or only components of it, depending on their operational function that might be assigned to them.

4. Experiences

The authors have had the opportunity to gain a lot of experience with the approach by supporting the development of the STANAG, by a feasibility study, and by developing the experimental system together with the prototype (see below).

The feasibility question focused on the availability of a priori data and their sensitivity, i.e. the impact of imprecise a prioris on the result. The answer was satisfactory: With known sensors and sources with at least some contribution to identification no problem occurs. Combining source outputs with inconsistent indications to allegiance may raise problems. These are, however, just the complex decision situations which are reliably detected by internal control mechanisms of the process and, if desired, brought to the attention of the operator.

Summarising, the process may be characterised as follows:

- It provides the necessary interoperability to exploit the synergy within various sensors and sources. So it can be seen as system of systems.
- It is a consistent and reliable process making the best assessment of information available.
- It is prepared to combine and assess any kind of information contributing to identification including future sensors and sources.
- The process has a high flexibility to be adjusted to any host systems needs and any operational condition (mobile, joint and combined mission), supporting any operational architecture.
- It is a substantial support to operators' tasks and reduction of load.

5. Experimental System

This paragraph is dedicated to a prototype system which allows assessments in terms of technical and operational performance.

It has been developed and adapted to a Control and Reporting Centre (CRC) in order to

- adapt the generic IDCP process to a typical operational environment,
- use common identification procedures in peace and war,
- use available simulated and live data,
- show the operational benefit,
- allow the reuse of the system in other environments or studies and
- allow a flexible adaptation and configuration to other requirements.

Results in terms of processing performance, flexibility, adaptivity, robustness, reliability, and operational benefit were won in the project.

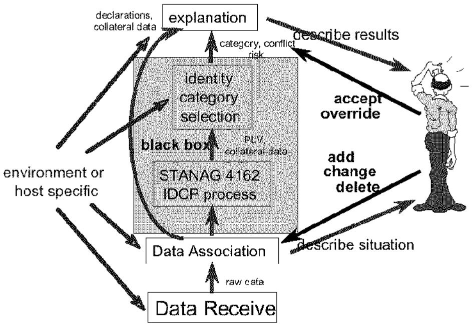
Additionally the experimental system was installed at the NC3A.

The adaptation of the data fusion process to the operational environment consisted of three major steps:

- Architecture
  The definition of a system architecture considers interfaces to existing data sources, processes prior to data fusion like correlation

and association of the source data and processes after the data fusion e.g. result presentation, data fusion explanation and operator interaction.

- Configuration
  This includes the definition of a priori data and environment specific data bases to configure the system to a specific operational environment and scenario. This means, that operational procedures have to be analysed, whether they should impact the process of data fusion and how these should be reflected in the behaviour of the system. Furthermore the system has to present the received data and the results of the fusion in an way that the operating personal trusts and understands the system.



Embedded Data Fusion

- Testing
  Experience is gathered by testing the system. Live data behaves different than specifications may give the impression. The parameters controlling the processes depend on the quality of the received data and can be optimised only in intensive test periods. Software reliability can only be ensured with a careful analysis of all parts of the system using a high amount of source data.

Based on our experiences we would make the following conclusions concerning the implementation of an data fusion system in an operational environment:

- The generic data fusion process as defined in the STANAG 4162 can be easily adapted to the operational environment.
- Additional processes are necessary to embed this data fusion process in a system. These processes are not standardised and ensure that the adaptation to environment specific requirements is possible. The implementation might be complex and can contribute to the system performance in the same way as to the quality of the data fusion process itself.
- The design of a high performance data fusion system requires a deep understanding of operational requirements and procedures. A specific aspect is that the system provides only reasonable results if operational experience was successfully transferred in the behaviour of the system.

6. Way Ahead

Future steps in order to exploit the concept for a maximal operational benefit could be as follows:

- Gradual implementation, provision for new systems
- Expansion to new regimes like air - ground and ground - ground
- Definition of networks and forwarding information exchange requirements for tactical data links
- Use of future sensors and sources

References

Caromicoli, A., Kurien, T. Multitarget Identification in Airborne Surveillance. SPIE Vol. 1098 Aerospace Pattern Recognition 1989

DuPree, J., Antonil J. Information Measures Unify Decision Making. USAF Rome Laboratory/IRAP, April 1997

Fagin, R., Halpern, J. A new approach to updating beliefs. Uncertainty in Artifical Intelligence 6, Elsevier Science Publishers B.V: 1991

Hall, David L. Mathematical Techniques in Multisensor Data Fusion. ARTECH HOUSE, INC. 1992

Leung, H., Wu,J. (2000) Bayesian and Dempster-Shafer Target Identification for Radar Surveillance. IEEE Transactions on Aerospace and Electronic Systems Vol 36 No. 2 April 2000

NATO. (2000) Standardisation Agreement 4162 Technical Characteristics of the NATO Identification System (NIS), March 2000 version of Annexes C and D

Rehfeldt, M. Mathematical Description of an IDCP extension. IABG Working Paper, 1991

Schneider, F., Stroscher, C. Integration of an IDCP Experimental System into a CRC. IABG reports 1998, 2000

Stroscher, C. Series of IABG Working Papers in support of STANAG 4162 development. 1991 to 2000

Waltz, E., Llinas, J. Multisensor data fusion ARTECH HOUSE, INC. 1990